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Consumer awareness in the adoption of microgeneration technologies An empirical investigation in the Republic of Ireland

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ABSTRACT

Despite major policy and marketing efforts, the uptake of microgeneration technologies in most European countries remains low. Whereas most academic studies and policy reports aim to identify the underlying reasons why people buy these new technologies, they often fail to assess the general level of consumer awareness. The process of adopting an innovation, however, shows that awareness is a prerequisite which needs to be understood before adoption can be addressed. This paper takes a closer look at awareness of microgeneration and presents the results from a nationally representative study conducted in the Republic of Ireland. Findings from logistic regressions clearly indicate that awareness varies significantly between the individual technologies and customer segments. The paper concludes with implications for policy makers and marketers aiming to promote microgeneration technologies in consumer markets.

Contents

1. Introduction

In 2007 the European Commission laid out a comprehensive energy policy roadmap[1] for Europe which was later that year translated by the European Spring Council into ambitious targets for renewable energy, energy efficiency and greenhouse gas emission reduction. Overall, the council set a legally binding target of a 20% share of renewable energies in overall EU energy consumption by 2020. The Irish government further launched an Energy *White Paper*[2] in which it set out the country's energy policy directions and an

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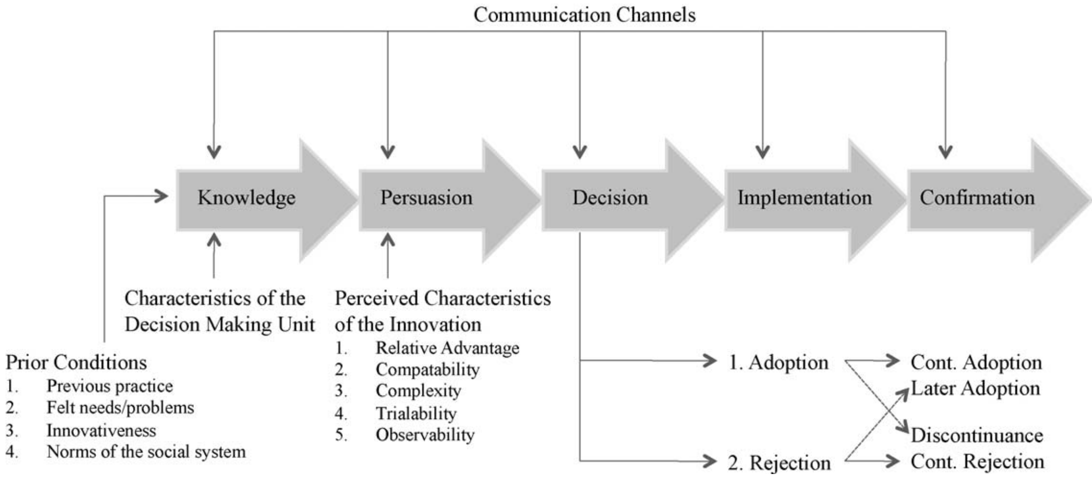


Fig. 1. The adoption of innovation process.*Source*: [15].

additional target of meeting 40% of Ireland's total demand for electricity from renewable sources by 2020. In this context microgeneration technologies like *Photovoltaic Panels*, *Micro Wind Turbines*, *Solar Water Heating*, *Biomass Boilers*, *Heat Pumps* and *Combined Heat and Power Generation* (CHP)[3] will have an increasingly important role to play, as they provide a great potential to contribute to the reduction of greenhouse gas emission, ease fossil fuel dependency and stabilize energy costs [1]. Yet, to have a significant impact on the macro-level and help contributing to Ireland's ambitious energy targets, it requires the aggregate actions of individuals to undertake investments into these technologies.

Despite major marketing and public policy efforts the diffusion of these technologies in most European countries is slow and microgeneration technologies can be referred to as *resistant innovations*. Unlike *receptive innovations*, these products face slow take up times as they require consumers 'to alter existing belief structures, attitudes, traditions or entrenched routines significantly' [2, p. 83].

Market acceptance was recently identified as the most under researched angle in the area of renewable energies [3]. However, existing studies have pre-dominantly analysed consumers' *intention to adopt* (e.g. [4–7]) or *willingness to pay* (WTP) (e.g. [8–14]) for microgeneration technologies or renewable energy. Although the two approaches vary in the conceptualisation of adoption, both implicitly assume that consumers are aware of the innovation in question. However, little or no research is available to help us understand consumer awareness of microgeneration technologies. Many consumers might not have spent much time considering these green innovations or, more importantly, are not aware of their existence at all. Consumer awareness may vary depending on the backgrounds/market segment of the consumers and the specific technology in question.

The purpose of this study is to address this gap in the literature with an exploratory study of the overall consumer awareness of microgeneration technologies and the effects of demographics on the awareness of six different technologies. In light of the diffusion of innovation process, the following section highlights the importance of understanding consumer awareness. We then present the results of a nationally representative survey of awareness of microgeneration technologies among the Irish population, showing great differences in awareness between technologies and consumer segments. The paper concludes with implications for policymakers and marketers and suggestions for further research.

2. Literature review

2.1. The adoption decision process

From a theoretical point of view, awareness precedes adoption in the adoption of innovation process [15]. In the innovation literature the adoption decision process is usually referred to as a 'hierarchy of effects' model (e.g. [16]). Roger's [15] model of the adoption decision process is the most popular, assuming that consumers go through five phases: *knowledge*, *persuasion*, *decision*, *implementation*, *confirmation* (Fig. 1).

The model suggests that the innovation decision process commences when an 'individual (or other decision making unit) is exposed to an innovation's existence and gains an understanding of how it functions' [15, p. 171]. Awareness of an innovation generally depends on personality or socioeconomic characteristics like age or social class. However, some consumer segments appear to be generally more receptive towards new ideas and often function as strategically important target groups for marketers and policy makers to stimulate the diffusion of innovations like microgeneration technologies.

Persuasion is the next stage in which a consumer, once aware of the innovation, forms a favourable or unfavourable attitude towards the new product. Attitudes are mostly dependent on the beliefs about the perceived product characteristics. Having evaluated the product characteristics, at the decision stage consumers than make a choice to adopt or reject an innovation. Rogers [15, p. 177] defines adoption as the decision 'to make full use of an innovation as the best course available.' On the implementation stage, the consumer actually adopts (i.e. purchases) the innovation and evaluates its usefulness. Finally, on the confirmation stage, the consumer decides whether or not to continue using it.

It should be noted that consumers, regardless of at which stage of the adoption decision process, can be exposed to communication in the form of marketing or public policy campaigns. Yet, in order for any message to be effective it needs to be tailored to the respective target audience. Consumers at the very first stage of the adoption process (i.e. awareness) are likely to respond to different messages and information than consumers who are currently evaluating the innovation's characteristics (i.e. persuasion). Gaining an understanding of who is aware of what and what (socioeconomic) factors have an influence on the level of

[3] CHP is technically not a 'renewable', however, it is included here as it has the potential to save significant amounts of energy and reduce carbon emissions.

awareness can therefore be vital for marketers and public policy makers to more effectively promote the diffusion of microgeneration technologies.

Further, ignoring differing levels of awareness in research around adoption of microgeneration technologies can lead to nonresponse bias [17] which can result in distorted findings and policies. Respondents who have not heard about the subject of the survey (i.e. microgeneration) might be less interested and hence less likely to participate. For example, studies aiming to understand willingness to pay for microgeneration technologies might overstate the population's true WTP as people who are unaware of the innovation might be less likely to participate in the survey. The respective literature provides various methods to assess nonresponse bias (e.g. [18]). A common approach is to compare the distribution of socio-demographic variables from the survey results with the latest census data for the population. However, knowing differences in awareness among socio-demographic subgroups beforehand allows researcher to account for these differences prior to the survey and, for example, to stratify the sample. Conversely, those respondents who are unaware of a specific technology may well respond negatively on WTP, for lack of knowledge, rather than to express an opinion on a technology. In either case, lack of awareness by respondents, would threaten the validity of the findings relative to intention to purchase or WTP.

3. The awareness study

3.1. Research objective

The motivation of this study was to gain a better understanding of the overall and relative levels of awareness for microgeneration technologies in the Republic of Ireland. Further, the study aimed to understand socio-demographic factors which influence the likelihood of awareness and to highlight the implications for practitioners and researchers. As it is very little known about consumer awareness and microgeneration technologies, no hypotheses were formulated and the study is primarily exploratory in nature.

3.2. Survey design and question

In March 2009 a survey was developed to identify the level of awareness for microgeneration technologies in Ireland. The study was administered by a professional market research company alongside a larger fortnightly telephone omnibus survey of the Irish adult population. The survey accessed a fresh sample of $n = 1010$ adults aged > 15 years and ensured representativeness by setting strict quotas for age, gender, social class and region. Further, sample leads were generated via Random Digital Dialling (RDD) which included 40% mobile phones.

A small qualitative pilot-study revealed that many people were not familiar with the term microgeneration. Respondents in the survey were therefore provided with a short introduction referring to microgeneration as '*renewable energy technologies people can install in their homes for heating and electricity production*.' This brief explanation was followed by the questions about the individual technologies. Each question started with '*have you heard of, or seen anywhere*' followed by a short explanation of the technology like '*solar water heaters or solar thermal collectors which are placed on a roof to produce hot water from sunlight?*'.

The responses were collected in a dichotomous yes/no format and were followed by various questions about socio-demographic factors including age, gender, marital status, social class, household size, geographic location and Internet Access.

3.3. Empirical model

In order to test the influence of socio-demographic factors on the level of awareness, the authors utilized a common microeconometric logit model. Total awareness for microgeneration technologies and awareness for each individual technology were tested in separate frameworks.

3.4. Measuring overall and technology-specific awareness

In a first step determinants of total awareness of microgeneration technologies were tested. In this model, the dependent variable was constructed as the sum of the binary responses for the individual technologies and used as a proxy for *overall awareness* of microgeneration, ranging from 0 to 6. The explanatory socio-demographic variables were than regressed on seven possible outcomes of awareness. A common approach in the respective literature is to employ a multiple logit model with simultaneous regressions on the individual outcomes [19]. This method assumes the outcomes to be ordered but independent from each other. However, as the employed variable (i.e. sum of answers) serves as a proxy for overall awareness, it can be argued that despite ordinal outcomes the distances between the seven outcomes are an indication for differences in awareness. In this case, an ordered logit model is more appropriate for the analysis.[4] The general form of the presented model can be formulated as follows:

$$y* = \beta_1' X_{1i} + \beta_2' X_{2i} + \varepsilon, \quad \text{where } y = \begin{cases} 1 \text{ if } y* \leq 0 \\ 2 \text{ if } 0 < y* \leq \mu_1 \\ 3 \text{ if } \mu_1 < y* \leq \mu_2 \\ 4 \text{ if } \mu_2 < y* \leq \mu_3 \\ 5 \text{ if } \mu_3 < y* \leq \mu_4 \\ 6 \text{ if } \mu_4 < y* \leq \mu_5 \\ 7 \text{ if } \mu_5 < y* \leq \mu_6 \end{cases}, \qquad (1)$$

In this model y^* is the unobserved latent outcome (i.e. overall awareness) and X_1 a set of explanatory variables representing individual characteristics including age, gender and employment status. X_2 represents a set of household characteristics like social class, spatial location and a measure for Internet accessibility. All other unobserved influences are captured in the error term ε.

In order to capture awareness for the individual technologies, the same explanatory variables were regressed on the binary outcomes in six separate logit models. The general functional form of the logit models is denoted as follows:

$$y_i^* = \beta_{1i}' X_1 + \beta_2' X_2 + \varepsilon_i, \quad \text{where } y_i = \begin{cases} 1 \text{ if } y_i^* > 0 \\ 0 \text{ otherwise} \end{cases} \qquad (2)$$

In these models, the dependent variable y^* is binary coded and takes on the value 1 if the respondent states they are aware of the microgeneration technology in question and 0 if otherwise. The explanatory variables were scaled the same way as in the ordered model, with X_1 representing individual and X_2 household characteristics.

3.5. Antecedent of awareness

In both models, the variable *Age* reflects a person's individual age in years. Because an inverted u-shaped functional form was expected, a squared age (*Age*^{2}) was also included in the estimation. Further, the model contains a dummy variable *Gender* which takes on the value 1 if the respondent is female and 0 if otherwise. *Employed Fulltime*, *Employed Part-time*, *Unemployed* and *Other* are binary coded dummy variables, indicating a person's employment status. Other includes individuals who are not actively participat-

[4] For a more general discussion see: Greene (2008) pp. 831–862.

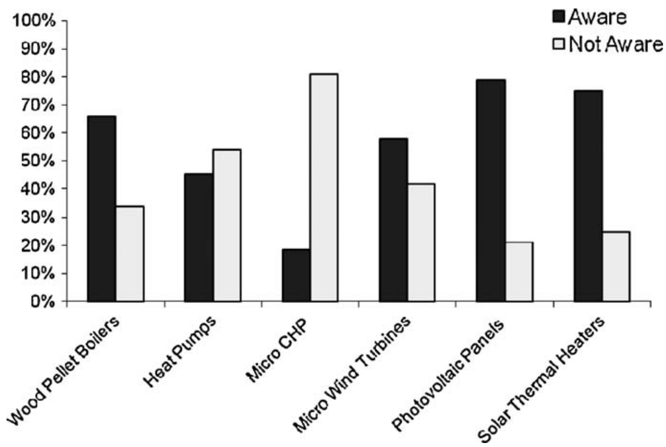


Fig. 2. Overall level of awareness for microgeneration technologies among the Irish population.*Source*: own calculation.

ing in the labour market like housewives, students and retired people. In the analysis Other was used as a reference group and coded as 0.

The set of household characteristics contains information about the individual's direct environment. The variable *Householdsize* reflects the number of people living in the respondent's home and is a linear measure. *Social class* of the respondent is also included and mainly reflects the vocation of the chief income earner. Households in which the chief income earner is working (or has worked until retirement) in senior management positions or as a top level civilian servant are categorised as *upper to middle class* whereas people in middle management positions or non-manual positions are labelled as *middle class*. Chief income earners in skilled or semi-skilled manual jobs are labelled *working class* and a fourth category included are *farmers*. In the model, working class was chosen as the reference variable and coded 0. The third household characteristic is *Internet Access*. It provides information on the respondent's access to the Internet and is a binary coded dummy variable. The sample was further broken down geographically into the four main regions: *Connacht/Ulster*, *Rest of Leinster*,[5] *Munster* and *Dublin*. The latter was used as a reference group and coded 0.

3.6. Analysis and results

3.6.1. Descriptive results

A first glance at the data reveals that the level of awareness for the individual technologies differs significantly. As illustrated in Fig. 2, almost 80% of the Irish population has heard of or seen Photovoltaic Panels, but only 18% are aware of Micro CHP. The other technologies fall between these two extremes with a 75% level of awareness for Solar Thermal Heaters, 66% for Wood Pellet boilers, 58% for Micro Wind Turbines and 45% for Heat Pumps.

However, the really interesting question was if socio-demographic differences can explain the overall awareness for microgeneration and differences between technologies.

3.6.2. Logistic regression results

After accounting for missing values, the final sample consisted of $n = 984$ respondents. The estimations were performed with the standard procedures for logit and ordered logit models. In order to test for the overall significance for each model, a commonly presented likelihood-ratio test (LR) was applied [20]. Because goodness of fit measures, like McFadden-Pseudo-R^2 are only of

Table 1
Ordered logit model for total awareness of microgeneration technologies.

Variable	Total awareness	
	Coefficient	Std. Err.
Gender	-0.459^{***}	0.120
Internet Access	0.672^{***}	0.189
Age	0.056^{***}	0.005
Age^2	-0.00051^{**}	0.00023
Householdsize	-0.00881	0.139
Region (rest of Leinster)	0.728^{***}	0.160
Region Munster	0.025	0.156
Region Connacht/Ulster	0.517^{***}	0.174
Region Dublin	–	–
Employed fulltime	0.294^{*}	0.169
Employed part-time	0.169	0.188
Unemployed	0.627^{**}	0.250
Other	–	–
Upper-middle class	0.416^{**}	0.199
Middle class	0.096	0.150
Farmer	0.090	0.242
Working class	–	–
κ_1	-0.811^{**}	0.450
κ_2	0.282	0.439
κ_3	1.157^{**}	0.439
κ_4	2.012^{***}	0.443
κ_5	3.094^{***}	0.448
κ_6	4.882^{***}	0.464
Number of observations	984	
LL(0)	−1783	
LL	−1733	
LR test χ^2 (15)	99.98^{***}	
Pseudo-R^2 McFadden	0.028	

Source: own calculations.

* $p < 0.1$.
** $p < 0.05$.
*** $p < 0.01$.

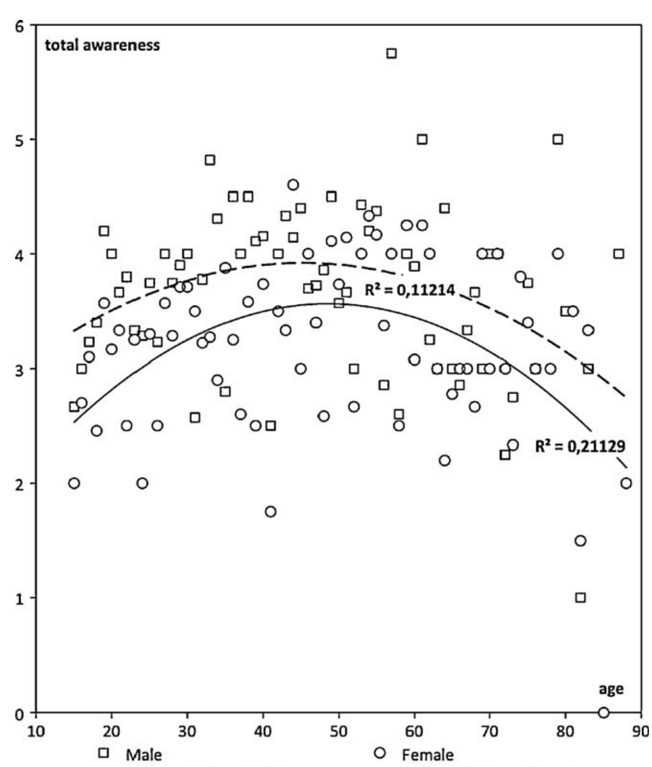


Fig. 3. Inverted u-shape of age–awareness relationship.*Source*: own calculation

[5] Dublin is a city within the region of Leinster which is therefore referred to as Rest of Leinster.

Table 2
Logit models for the awareness of individual microgeneration technologies.

Variables	Solar water heater		PV panels		Micro Wind		Micro CHP		Heat pumps		Wood pellet	
	Coefficients	Std. Err.	Coefficients	Std. Err.	Coefficients	Std. Err.	Coefficients	Std. Err.	Coefficients	Std. Err.	Coefficients	Std. Err.
Gender	−0.269*	0.163	−0.242	0.165	−0.290**	0.140	−0.437**	0.180	−0.554***	0.140	−0.295*	0.156
Age	0.027	0.026	0.011	0.027	0.0724***	0.023	−0.025	0.032	0.0235	0.024	0.126***	0.025
Age^2	−0.0002	0.0003	−0.0001	0.0003	−0.0008***	0.0003	9.68e^{-05}	0.0004	−0.0001	0.0003	−0.001***	0.0003
Internet Access	0.849***	0.240	0.547**	0.238	0.485**	0.215	−0.011	0.291	0.726***	0.224	0.432*	0.243
Householdsize	0.0002	0.052	0.002	0.051	−0.041	0.044	0.049	0.053	0.026	0.044	0.013	0.050
Region Leinster	0.411*	0.222	0.311	0.220	0.588***	0.184	0.163	0.221	0.651***	0.185	1.017***	0.214
Region Munster	−0.181	0.204	−0.042	0.258	0.258	0.180	−0.497**	0.247	0.046	0.184	0.334*	0.194
Region Connacht/Ulster	0.394	0.247	0.360	0.249	0.472**	0.207	−0.124	0.263	0.647***	0.209	0.829***	0.234
Region Dublin	–	–	–	–	–	–	–	–	–	–	–	–
Employed fulltime	0.303	0.229	−0.092	0.232	0.039	0.197	0.284	0.266	0.612***	0.202	0.037	0.221
Employed part-time	−0.077	0.244	0.128	0.262	−0.003	0.218	0.022	0.300	0.570***	0.223	−0.036	0.242
Unemployed	0.102	0.318	−0.015	0.323	0.159	0.281	0.561	0.344	0.915***	0.284	0.157	0.314
Other	–	–	–	–	–	–	–	–	–	–	–	–
Upper-middle Class	−0.150	0.267	0.357	0.278	0.118	0.231	0.190	0.284	0.607***	0.234	0.453*	0.262
Middle class	−0.070	0.208	0.158	0.206	−0.005	0.177	−0.158	0.230	0.180	0.179	0.173	0.198
Farmer	−0.049	0.333	−0.281	0.311	0.283	0.289	−0.041	0.364	0.124	0.282	−0.183	0.316
Working class	–	–	–	–	–	–	–	–	–	–	–	–
Constant	−0.327	0.573	0.493	0.590	−1.563***	0.505	−0.611	0.646	−2.166***	0.519	−2.895***	0.558
Number of observations	984		984		984		984		984		984	
LL(0)	−530.3		−519.1		−665.5		−462.1		−681.5		−584.9	
LL	−511.7		−509.4		−643.4		−443.4		−635.8		−540.3	
LR test χ^2 (16)	37.06**		19.48		44.63***		37.02***		91.52***		89.12***	
Hosmer–Lemeshow Stat.	0.3726		0.4023		0.2905		0.3239		0.3750		0.2242	
Pseudo-R^2 (McFadden)	0.0350		0.0188		0.0328		0.0401		0.0671		0.0762	

Source: own calculations.

* $p < 0.1$.
** $p < 0.05$.
*** $p < 0.01$.

limited use, the Hosmer–Lemeshow specification test is also presented for both models [21].

The results of the ordered logit model (Eq. (1)) give general evidence for socioeconomic influences on the overall awareness of microgeneration technologies. The likelihood-ratio test indicates that the exogenous variables are statistically significant at all levels of confidence (see Table 1).

For the overall level of awareness for microgeneration technologies the results show that woman are less likely to be aware of the respective technologies (-0.459, $p < 0.01$). Although gender and green consumption have been a long researched issue (e.g. [22]) the relationship between gender and renewable energy is a relatively new field of study primarily researched in a development context (e.g. [23,24]). Research around green consumerism suggests that woman are often more aware or concerned about environmental issues (e.g. [25]), yet the findings in this study indicate the opposite and thus provides scope for further investigation.

Further, there seems to be a positive relationship between age and awareness (0.056, $p < 0.01$), implying that older people are more likely to be aware of microgeneration technologies. However, applying the different functional form for the age variable (Age^2), the coefficient turns negative (-0.00051, $p < 0.05$). This finding indicates that the relationship between age and awareness is of an inverted u-shape, with young and older people less likely to be aware of microgeneration (Fig. 3).

Whereas older people were expected to be less aware of microgeneration technologies, low levels of awareness for young people are somewhat surprising as 'the general belief is that younger individuals are likely to be more sensitive of environmental issues' [22, p. 559]. Yet, environmental concerns might not be as closely linked to microgeneration technologies as one would expect. In fact, microgeneration might be closer associated with energy-cost savings and is therefore more of a concern for homeowners, which would explain higher levels of awareness among middle-aged people.

The results also show that people in employment are more likely than students, housewives or pensioners (*Others*) to have heard of microgeneration technologies (0.294, $p < 0.1$). Somewhat surprisingly, respondents out of employment were also significantly more likely to be aware of microgeneration (0.627, $p < 0.05$). This result might be somewhat distorted as due to the global recession, unemployment rates in Ireland doubled from 5.2% in March 2008 to 10.8% in March 2009.[6] During this period a lot of high-skilled and well-educated people were made redundant, possibly contributing to high levels of awareness among the unemployed group.

Taking a closer look at the household characteristics, the findings show that *Householdsize* did not appear to have a significant impact. However, *social class* does seem to have a small but significant effect, with respondents from the upper-middle class category showing higher levels of awareness than the other groups (0.416, $p < 0.05$). As social class is quite likely to be correlated with income and education, these results were expected as microgeneration technologies are still very high-cost and high-involvement products.

Finally, the data also confirm regional differences, with respondents living in Rest of Leinster (0.728, $p < 0.01$) and Connacht/Ulster (0.517, $p < 0.01$) being more likely to have come across microgeneration technologies than people living in Dublin and Munster. The city of Cork is located in Munster and is Ireland's second largest city after Dublin. People living in both Munster and Dublin are less likely to be aware of microgeneration, indicating a split between rural and urban areas. One explanation could be that more people in urban areas live in apartments and therefore have less interest in microgeneration technologies. This phenomenon is also known as the landlord–tenant dilemma (e.g. [27]). In a situation where a dwelling is rented, neither the landlord nor the tenant may have an incentive to invest in energy saving measures. Often unaware of the true energy costs, tenants, for example, might not feel the need to push for an investment that lowers their monthly energy-bill thus being less aware of any potential energy saving technologies available. Landlords on the other hand only have an incentive to buy a microgeneration technology if they can increase the rents and thus recoup the investment. Another consideration may be the difference in the type of housing stock between urban and rural. The urban stock is largely made up of speculatively built housing estates where the purchaser is offered little or no choice in the details of construction. In comparison, a large part of the rural housing stock is one-off dwellings where the owner will often have had a significant say in the nature and detail of construction leading to possible familiarity with microgeneration technologies.

Although the levels of awareness for the technologies differ significantly, logistic regressions for the individual technologies (Table 2) reveal that the antecedents of awareness are quite similar between technologies. Like in the first model, gender had the most consistent impact, with male respondents being more aware of all technologies except PV panels, for which no significant differences could be found. With 79% awareness, PV panels had the highest level of awareness among the Irish population so that gender differences might have been washed out by the overall high level of awareness. A look at the other variables also reveals that, except from *Internet Access*, none of the socio-demographic variables or household characteristics had a significant influence on PV awareness.

Internet Access is a statistically significant predictor of awareness across all technologies (except Micro CHP) and is the most consistent predictor of awareness of microgeneration technologies among the individual and household characteristics assessed in this study. It is not surprising that those who have adopted the Internet may be more aware of or interested in new technologies than those who have not yet adapted the Internet.

The other main predictor of awareness was region. The biggest differences could be detected for Micro Wind Turbines, Heat Pumps and Wood Pellet Boilers with people in Leinster and Connacht/Ulster having higher levels of awareness than the rest of the country. Whether this is due to greater marketing efforts in these areas or due to the earlier mentioned split between rural and urban areas also remains a question for further investigation.

4. Conclusion

The adoption of innovation process has shown that awareness and knowledge of microgeneration technologies precedes consumers' evaluation of product characteristics and thus their adoption decisions. Having a general understanding of the overall level of awareness and the differences between customer segments holds valuable information for marketers and public policy makers who aim to promote the diffusion of microgeneration technologies.

The analysis has shown that awareness among the Irish population for the individual technologies differs significantly. Whereas only 18% of respondents had heard about Micro CHP, about 80% were aware of PV panels. However, more importantly the results revealed great differences in awareness levels among consumer segments. The analysis of the socio-demographic variables indicates that men were significantly more likely to have heard of microgeneration technologies. However, as previous research shows, women are often more concerned about the

[6] Seasonally Adjusted Standardized Unemployment Rates (SUR) [26].

environment and increasing levels of awareness among the female population might provide leverage to more effectively promote microgeneration in Ireland. Further, the analysis of age differences indicates that younger people in Ireland are less likely to be aware of microgeneration technologies. Educating children and young adults in schools and universities is not only vital to promote microgeneration among future home-owners but also provides an important vehicle to raise awareness among their parents. The split between people with and without Internet also shows that nowadays the Internet provides an ever-increasing platform to raise awareness and provide appropriate information for people who are interested in applying these technologies at their homes. Further, the study indicates that there is scope to raise awareness in urban areas.

Whereas this awareness study provides a comprehensive overview of awareness levels for different technologies and differences between consumer segments it cannot offer any coherent explanations for these findings, thus providing scope for further research around peoples' attitudes towards and willingness to pay for microgeneration. However, awareness-studies can serve as a first step and offer guidance on sampling issues and avoid selection bias like nonresponse.

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